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INTERACTIONS OF ECONOMIC THEORY

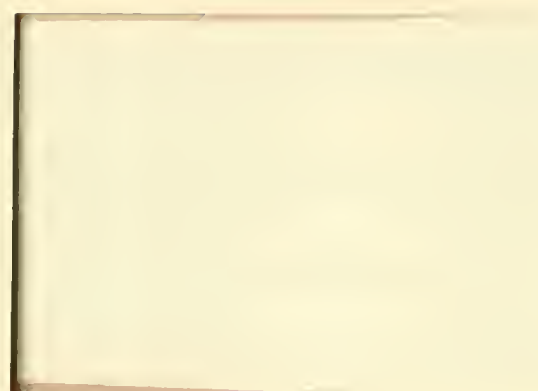
AND OPERATIONS RESEARCH*

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Interactions of Economic Theory and Operations Research

In the last few years an increasing amount of attention has been paid to the theoretical and technical developments that have evolved from the interaction of economic theory and operations research. During this period a number of papers have appeared which review the advances that have taken place in economic theory as well as in the techniques of operations research.^{1/} Some of these papers have been directly concerned with the interplay between these two bodies of knowledge.^{2/} Hence it would be redundant for me to devote this paper to retracing developments that have already been well noted and discussed. As a result I shall not present a complete history of these interactions but rather shall focus upon two important innovations that occurred as a direct consequence of the activity of economic theorists and operation researchers. The first of these innovations is the modified concept of rational behavior known as "satisficing"; and the second is the technique of theory and model construction known as "heuristic programming". Customarily these two notions are presented and discussed independently from each other. But it is the combination of these two ideas that has led to what I am going to take the liberty of calling, one of the major advances in our knowledge of organizational and individual decision-making behavior. In order to point out the effects that these two concepts have had both on

^{1/} See, for example, the excellent review articles of H. A. Simon, "Theories of Decision-Making in Economics," American Economic Review, Vol. XLIX, June 1959, pp. 253-283; and R. Dorfman, "Operations Research," American Economic Review, Vol. L, September, 1960, pp. 575-623.

^{2/} See the papers presented by W. W. Cooper, W. J. Baumol, and C. J. Hitch and R. N. McKean for the symposium on "Managerial Economics: A New Frontier?" to be found in the Papers and Proceedings of the AEA, American Economic Review, Vol. LI, May, 1961, pp. 131-155.

the economic theory of the firm and on the practice of operations research, this paper is divided into three main sections. The first part is devoted to a brief description of some of the important changes in the theory of the firm that have been brought about by the introduction of the satisficing concept of behavior. The second contains a brief description of the development of heuristic programming as well as an actual example in which the satisficing concept and the technique of heuristic programming are corjoined in the solution of a complex business problem. And the third section is devoted to an attempt to assess the implications of these two innovations both for general economic theory and its policy considerations as well as the practice of operations research.

I. Developments in the Theory of the Firm

To be able to trace a change or development in a theory, one must first have a point at which to begin. For our purposes, the starting point will be the classical or conventional theory of the firm. Unfortunately, there is considerable disagreement among economists as to precisely what is The Theory of the Firm. Since no one theory has been graced with this title for any length of time, I shall present what I consider represents a reasonable consensus of opinion.

1. Classical Theory^{3/}

The classical theory of the firm is a theory of market behavior.

^{3/}

For a more detailed and extensive description of the classical theory of the firm see: J. M. Henderson and R. E. Quandt, Microeconomic Theory, McGraw-Hill, New York, 1958, especially pp. 42-84.

It is concerned with explaining at a general and aggregated level the allocative process of the market place. In particular the theory takes as its objective the explanation of the behavior of firms, and consequently the allocation of resources between firms under varying market conditions, e.g. pure competition, oligopoly, and monopoly. The firm in this theory is an entity whose objective is to maximize its net revenue (profits). The firm sets out to accomplish this objective by taking the prices of its inputs (labor, materials, equipment, and capital) as being given to it by the market place. It then examines its production function which is taken to be determined by the current state of technology. To maximize its net revenue the firm then decides upon the particular combination of inputs and outputs that is optimal with respect to the given prices and the production function.

In the market condition known as pure competition the firm is allowed to sell at a given price whatever quantity of finished product it produces. In this situation the theory is concerned with specifying the conditions under which such an optimum can be attained. In particular, in the case where we are dealing with firms that only produce one product the theory states the optimum position will be reached if the output is adjusted so that the marginal cost of producing this number of items is exactly equal to the marginal revenue derived from their sale. The theory also extends to multiproduct firms and specifies the optimal procedures whereby these firms can decide how much of each good it should produce. After specifying the conditions under which firms, engaging in pure competition,

can maximize their net revenue, the theory is then concerned with explaining the effects of changes in the prices of products and factors of production which result from alterations in the equilibrium position of the total market.

Because all markets do not meet the conditions of perfect competition, the theory also extends to meet cases where either the market for the factors of production is imperfect, or the market for final products is imperfect, or both. One case in particular has received a considerable amount of attention. This is the market condition called oligopoly where a small number of producers effectively dominate the market for a product or a specific set of products. In this case there are a number of contending theories whose primary object is to specify the manner in which, for example, firm A takes into account the pricing and output decisions of firms B and C.^{4/} However, in all these extensions to different market conditions the theory retains the same internal decision-making process--namely, it is the object of each firm to maximize its profit. Thus, while the classical theory of the firm has been extended to meet various market situations its primary purpose has remained unchanged. Its object is to specify the mechanisms by which resources are allocated in the market place.

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For a survey of some recent theories of oligopoly see: Franco Modigliani, "New Developments on the Oligopoly Front." Journal of Political Economy, Vol. LXVI, June, 1958, pp. 215-232.

Lately this theory, or collection of theories, has come under attack from a number of quarters. Some critics have argued that firms do not decide how much to produce by equating marginal cost with marginal revenue. As evidence they point to the difference between the economic concept of cost found in the theory as against the accounting concept of cost used in actual business firms.^{5/} Other critics have noted that the theory does not view the firm as an organization and ignores the existence of such items as management planning, budgets, standard operating procedure and the host of other components which they argue should be included in a theory of a firm's decision-making process.^{6/} Essentially these and many other criticisms reflect the central fact that the classical theory of the firm was constructed to explain, at a general level, the behavior of firms within a given market and not the behavior of individuals within a particular firm. Consequently, these criticisms not only reflect the disparity between the behavior of actual firms and the firms of the theory, but also the directions in which the theory ought to be revised if it were to become a vehicle for explaining and predicting the variety of behavior exhibited in the market place as well as inside the firm.

^{5/} For example see: R. L. Hall and C. J. Hitch, "Price Theory and Business Behavior," in T. Wilson and P. W. S. Andrews (eds) Oxford Studies in the Price Mechanism, Oxford, 1951, pp. 107-138.

^{6/} A. Papandreou, "Some Basic Problems in the Theory of the Firm," in B. F. Haley (ed), A Survey of Contemporary Economics, Homewood, Illinois, 1952, Vol. 2, pp. 183-219.

2. Recent Revisions

As noted above, the many critiques are not so much comments on the inadequacy of classical theory to meet its stated goals as they are a set of suggestions to guide the development of a new micro theory of the firm. That is to say, the majority of suggestions pertain to the construction of a theory that describes and predicts the internal decision-making process of a firm. Most of these suggestions have come from economists who, while engaged in consulting and operations research capacities, found that the classical theory was not suited to their needs. For example, to quote a leading economist and fellow conferee, "I can say quite categorically that I have never encountered a business problem in which my investigation was helped by any specific economic theorem..."^{7/} As one might expect the disparity between theory and observable practices has stimulated economists to propose several new theories. And we shall now examine two of the principal classes of revisions that have taken place.

(a) Market Theories

The first major revision was proposed by Professor Baumol. From his observations of business behavior Baumol arrived at the conclusion that firms do not devote all their energies to maximizing profits. But rather that as long as a satisfactory level of profit is maintained a company will seek to maximize its sales revenue. This theory, which is worked out

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W. J. Baumol, "What Can Economic Theory Contribute to Managerial Economics?" Papers and Proceedings of the American Economic Association, op. cit. p. 144.

in some detail,^{8/} differs sharply in some respects from the classical theory out of which it grew. One obvious difference is that total sales revenue has been substituted for profits. But what is much more important is that the theory includes two decision criteria or objectives--namely, a satisfactory level of profit and the highest sales possible. In other words the firm is no longer viewed as working toward one objective alone. Instead it is portrayed as having to balance out two competing and not necessarily consistent goals.

From this principal hypothesis Baumol is able to draw several important conclusions which are more consistent with observed behavior than the conclusions drawn from conventional theory. The first of these is that firms faced with an increase in fixed costs will either pass these costs directly to the consumer in the form of higher prices, or they will try to reduce some expense over which they have some control, e.g. advertising expenditures. Conventional theory, on the other hand, asserts that changes in fixed costs (overhead) should not lead a firm to alter either its output or its prices. A second and rather important conclusion that Baumol draws is that, "sales maximization makes far greater the presumption that businessmen will consider non price competition to be the more advantageous alternative."^{9/} Classical theory asserts

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W. J. Baumol, Business Behavior, Value and Growth, Macmillan, New York, 1959, especially pp. 45-53.

^{9/}

W. J. Baumol, op. cit. p. 76.

that businessmen will consider price cuts or increases as the primary mechanism for increasing profits. But observations of business behavior do not support this dictum. On the contrary, firms appear to go to great lengths to set their prices at the same levels as their competitors while devoting their competitive energies toward advertising, product distribution, servicing, etc.

While Baumol's theory is clearly more consistent with observed behavior, its primary focus is upon the behavior of firms in the market place. The theory does not describe in any detail the decision procedures whereby firms are able to maximize their sales subject to their satisfactory-level-of-profit constraint. That is to say, even though a firm may wish to maximize its sales if it is not aware of the particular set of decisions and procedures that will lead it to this goal, then it is unlikely to achieve its objective. Skepticism with respect to this and other basic premises of the decision-making process contained in these market theories stimulated a second major type of revision.

(b) Behavioral Theories

Even though operations researchers have not been concerned with conducting large surveys of business practices, their exertions have produced samples of data on business decision-making which are strikingly at variance with the decision processes postulated in classical market theories. This divergence between theory and data has led some economists to abandon normative formulations--that is, trying to prescribe rules by which price and output decisions should be made--and concentrate on developing a body of theory that describes and predicts the actual decision processes

found in business firms. Instead of focusing on market mechanisms these theorists consider the firm as the basic unit. And they take as their objective the analysis and prediction of a firm's decision-making behavior on price, output, internal resource allocation, etc. To create such a theory, however, requires a knowledge of the major classes and attributes of business decisions. From such a research commitment it is easy to see how these researchers have been led to investigate the variety of alternatives facing business decision-makers as well as the processes by which choices are made. In brief, the object of this research is to discover how organizational objectives are formed, how decision strategies are developed, and how on the basis of these strategies conflicts are reduced and decisions made.^{10/}

The minute one abandons the classical notion that all firms have a single, universal goal, i.e. to maximize net revenue, and substitute for it the notion that firms have a variety of goals they try to satisfy, then a decision mechanism must be introduced that permits conflicts between objectives to be resolved. As noted above, Baumol retained the principle

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For examples of the literature on this research see: R. M. Cyert and J. G. March, "Organizational Factors in a Theory of Oligopoly," Quarterly Journal of Economics, Vol. LXX, 1956, pp. 44-64;

R. M. Cyert, W. R. Dill and J. G. March, "The Role of Expectations in Business Decision-Making," Administrative Science Quarterly, Vol. III, 1958, pp. 307-340; and R. M. Cyert and J. G. March, "Introduction to a Behavioral Theory of Organizational Objectives," in M. Haire (ed) Modern Organization Theory, New York, 1959.

of maximization in his market theory but made the pursuit of maximum sales revenue contingent upon the firm realizing, at the same time, an acceptable level of profit. But for a theory that intends to describe as well as predict the internal decision behavior of firms it is not sufficient merely to name a decision mechanism, e.g. maximize sales subject to a profit constraint. If the object is to describe decision behavior then the processes that are included in the theory must be defined in sufficient detail to allow the relevant decisions to be traced through the organization and tested against observable behavior. Mechanisms must be introduced that account for the processes by which a search for new information is initiated, the order in which alternatives are considered, and the order in which decisions are made.

The inclusion of these and other similar decision processes into a theory of firm behavior has led to the development of what has been entitled The Behavioral Theory of the Firm.^{11/} This is a theory of how an organization makes decisions on the basis of the information that is available at any given point in time. It is a theory of decision-making behavior which has substituted the notion of a satisfactory level of performance for the classical principle of maximization.

^{11/} For a complete statement of the theory and of the empirical research that has been conducted so far see: R. M. Cyert and J. G. March, The Behavioral Theory of the Firm, Prentice-Hall, Englewood Cliffs, forthcoming, 1963.

By abandoning the classical principle of maximizing for the behavioral principle of satisficing the theorist can add to his theory as many goals or objectives as are consistent with observed behavior. Each goal now enters the theory as a single constraint. And current performance on each goal is evaluated with respect to past and expected performance. Hence, the total number of objectives defines a set of satisfactory performance figures. A satisfactory level of performance on sales, for example, represents a level of aspiration with respect to sales which the firm will use to evaluate alternative decisions. The level of aspiration can rise or fall over time, but in the short run it performs the task of measuring the success of present performance. Current results are either satisfactory (good enough) or they are unsatisfactory (not good enough). And each goal enters the decision-making process with one or the other of these values.^{12/}

For example, consider the decision mechanisms included in a model that was designed to describe and predict the behavior of a firm entering a market previously dominated by one major producer.^{13/} In this duopoly

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For a more extensive discussion of the need for, as well as the characteristics of a satisficing decision mechanism see: J. Margolis, The Analysis of the Firm: "Rationalism, Conventionalism, and Behaviorism," Journal of Business, Vol. 31, July, 1958, pp. 187-199; and H. A. Simon, "A Behavioral Model of Rational Choice," Quarterly Journal of Economics, Vol. LXIX, February, 1952, pp. 99-118.

^{13/}

R. M. Cyert, E. A. Feigenbaum, and J. G. March, "Models in a Behavioral Theory of the Firm," Behavioral Science, Vol. 4, April, 1959, pp. 81-95.

model Cyert, Feigenbaum, and March outline the decision-making procedures used by each firm. The decision process consists of a sequence of individual decisions which finally result in each firm setting its output for the coming period. The output decision is made by first considering the competitor's reactions to any proposed changes in output over the previous period. Estimates of the demand for and the costs of producing this output are made, and the estimated profits are calculated to make sure that this profit is at an acceptable level. If a satisfactory level of profit is not obtained, then the firm searches for ways of reducing costs, revises its estimates of the demand for its product, and if necessary lowers the profit goal so that it is consistent with the revised cost and output figures. Although this model was not developed to reproduce the behavior of any particular firm, it was tested against the recorded history of the tin can industry. By specifying parameter values^{14/} for the model a stream of behavior was generated that closely paralleled some of the notable features of the behavior of the Continental Can Company from the time it entered the market as a competitor of the American Can Company.^{14/} Since a classical model of duopoly does not exist that can generate roughly comparable outputs on the basis of roughly comparable inputs, it is not possible to compare the performance of a classical model with this behavioral one. But it is possible to compare, at a fairly general level, the behavior of this behavioral model with the behavior of two specific,

^{14/}

Ibid, figs. I and II, pp. 91 and 92.

existing business firms. Whether this advance could have been made without the introduction of a satisficing mechanism is difficult to determine. That it was made with its inclusion is, of course, a matter of historical fact.

II. The Development of Heuristic Programming

At the same time that these revisions were taking place in the economic theory of the firm, advances were being made by operations researchers in the application of such techniques as linear and dynamic programming to business problems. Many production, scheduling and inventory problems are now being tackled and solved by the application of these and other mathematical tools.^{15/} But, a significant proportion of management's problems--namely, those whose structure is elusive and whose importance requires special treatment by middle and top management--are too complex to be successfully handled by current operations research techniques. Even though heroic simplifications can always be made there are a striking number of decision problems which are simply not amenable to current mathematical treatment. The answer appears to lie in the theory and technique of heuristic programming. And to understand what is meant and implied by this technique we must first briefly examine the theory of human problem solving from which this technique was developed.

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These techniques are discussed and many applications are noted in C. W. Churchman, R. L. Ackoff, and E. L. Arnoff, Introduction to Operations Research, New York, 1957.

1. A Theory of Human Problem Solving

The theory of human problem solving that we shall consider was developed by Newell, Shaw, and Simon^{16/} to explain and predict the decision-making behavior of humans engaged in solving specified tasks. The object of the theory is to explain the problem solving process by identifying the types of decision processes that humans use as well as the various decision mechanisms that permit these processes to be employed. A basic assumption of the theory is that thinking processes can be isolated as well as identified, and that they can be represented by a series of straight forward mechanical operations. This is not to say that thought processes are simple or easy to represent, but rather that they can be broken down into their elemental parts that in turn consist of collections of simple mechanisms. When these operations are recorded as a set of statements (decision rules) which describe the behavior under investigation, that behavior is said to have been "programmed".

Programs, however, can contain a wide variety of decision rules. When operations researchers apply their mathematical techniques to a business problem the programs they construct to produce a solution almost invariably

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A. Newell, J. C. Shaw, and H. A. Simon, "The Elements of a Theory of of Human Problem Solving," Psychological Review, Vol. 65, 1958, pp. 151-166.

employ algorithmic decision rules. These decision rules describe a set of procedures and calculations to be followed which guarantee that the required minimum or maximum will be found.

Humans, on the other hand, when engaged in solving complex problems do not employ these algorithmic techniques. Instead they use "rules of thumb" or "heuristics" to guide them in their search for solutions. For example, in a game of chess a good player may look three or four moves ahead on a number of possible plays. And by evaluating the consequences of these possibilities he will decide on his next move. If, however, algorithmic decision rules were employed to search for the "best" move he would now have to examine every possible move and its consequences before coming to a decision. If there were thirty possible moves that he could make and he examined each alternative for two moves ahead, then he would need to examine 30^4 , or roughly 800,000 possibilities before he could be sure that he had found the "best" move.^{17/} Clearly, chess players, like other human beings, are unable to consider 800,000 possibilities in a few minutes. Thus, the importance of rules of thumb or heuristics is that they frequently lead us to solutions which we would otherwise reach much more expensively, if at all, by algorithmic and other analytic techniques.

^{17/} For an excellent discussion of existing chess programs as well as the problems involved in constructing a heuristic chess program see: A. Newell, J. C. Shaw, H. A. Simon, "Chess-Playing and the Problems of Complexity," IBM Journal of Research and Development, Vol. 2, October, 1958, pp. 320-335.

When a program is constructed that attempts to reproduce the decision processes of a human problem solver the decision rules are in the form of heuristics. These programs are called heuristic programs and have two important characteristics. The first is the ability to determine, at any point in the decision process, its subsequent action by making choices between the alternatives that are available to it at the particular point in time. This property, called "branching" or "conditional transfer", allows a program to adapt itself to changes in the alternatives. Hence, heuristic programs can follow strategies. The second important characteristic is the capacity to use any set of sets of operations repetitively and recursively. In other words, a specific operation can be employed over and over again to perform the same function on a stream of inputs; or a decision rule can be applied to itself to form a hierarchy of the same operations to be applied to a specific set or sets of inputs. In this manner a heuristic program can use the same decision mechanisms to process different pieces of information or to solve quite different sets of problems.

Heuristic programming, then, is an attempt to incorporate into the theoretical structure of a model the selective, rule of thumb processes that humans employ in solving complex problems. It is a technique that has been used to reproduce parts of the thinking or problem solving process.^{18/}

^{18/} For an excellent example of the growing literature of this subject see: A. Newell and H. A. Simon, "Simulation of Human Thought," in Proceedings of the Conference on Current Trends in Psychology, University of Pittsburgh, 1959.

And more recently it has begun to be used as an aid in management decision-making.^{19/}

2. Heuristic Programming: An Example

To illustrate these remarks let us consider for a moment a heuristic program which was developed to solve assembly-line balancing problems.^{20/} Although no direct attempt was made to simulate a particular, human assembly-line balance, this program was modelled on the decision processes used by skilled human schedulers. The object of the program is to schedule or balance an assembly line.

The problem of scheduling an assembly line is similar to many other types of industrial scheduling problems, e.g., the scheduling of orders in a job shop, the routing of travelling salesmen, and the assigning of a given number of men to a given number of machines. The essence of these tasks is a combinatorial problem in which the elements of a set (the pieces that go to make up the final article, the orders in a job shop, etc.) are ordered or grouped on the basis of one or more criteria. While some of these problems have been tackled by standard operations research

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See, for example, H. A. Simon, The New Science of Management Decision, Harper and Brothers, New York, 1960.

^{20/}

F. M. Tonge, A Heuristic Program for Assembly-Line Balancing, Prentice-Hall, Englewood Cliffs, 1961.

techniques^{21/} they are frequently too large and complex to be solved by algorithmic procedures. For example, if the product to be assembled contains one hundred parts and we are looking for the most efficient way to assemble them, then to be certain we had located the best way we might have to inspect each of $100! = 9.3 \times 10^{157}$ possible arrangements. Now if we employed a high speed computer and inspected 10^6 orderings each second it would take 3×10^{114} years to cover them all. Clearly, blind search techniques of this sort are simply not feasible methods for solving combinatorial problems of any size.

The task of scheduling an assembly line consists of assigning the components making up the total assembly to work stations along the line. In order to consider an actual problem, Tonge's program assumes that the speed of the conveyer belt is fixed, e.g., there is constant production rate, and that the time required to assemble each component part is known. The goal of the program is to discover the minimum number of workmen that are needed to keep up with the given production rate and to meet the partial ordering constraints imposed on the assembly operation. Heuristics are employed to sufficiently simplify the task so that it can finally be solved by straight forward methods.

^{21/} For an excellent discussion of the application of linear programming to many of these problems see: A. Charnes and W. W. Cooper, Management Models and Industrial Applications of Linear Programming, John Wiley and Sons, New York, 1961.

The program consists of three main phases. The first is concerned with ordering the elemental tasks into fairly large sub-assemblies. Each of these sub-assemblies contains its own partial orderings between its elements. And each requires a certain amount of operating time. Hence, at the end of phase one the program has constructed a hierarchy of sub-assemblies. The second phase takes these sub-assemblies and assigns to them the required number of workmen. It then treats each sub-assembly as a separate scheduling problem and assigns the workmen to the various components of each sub-assembly. Having completed this rough scheduling of men and component parts phase three is then employed. This phase consists of a "smoothing" operation. It adjusts the components and the men among the work stations set up by the first two phases until the distribution of assigned time per worker is as even as possible.

Since this program was not designed to reproduce a specific scheduler's behavior, it is somewhat difficult to directly compare its performance with that of an industrial scheduler. However, the program was tested on a 70-element problem that was roughly similar to a particular industrial assembly line. Even though the industrial engineer had to contend with a few extra constraints the program's performance compared very favorably with that of the engineer's. For the 70- element problem the heuristic program required 23 men to complete the assembly operation as against the 26 men assigned to the task by the industrial scheduler. While this result by no means demonstrates the superiority of the heuristic program it is striking evidence of the power and versatility of this technique.

III Implications of These Innovations for Economic Theory and Operations Research

From the foregoing discussion it should be readily apparent that the introduction of the concept of satisficing and the technique of heuristic programming have already had a significant impact on the fundamental research conducted in the economic theory of the firm and in operations research. It should also be clear that the chief object of this research is to be able to explain as well as improve the decision-making behavior of individuals and organizations. Although most of this research is of very recent origins, sufficient progress has been made to tempt me to try and outline some of the implications this research should have both on the development of economic theory and on the guiding of business decisions.

(a) Economic Theory

First of all, it is my belief that the principal effect of the researches in decision-making behavior will be noticed in economic theory itself. For example, in section I it was noted that the empirical investigation of business decision procedures has led some economists to propose some extensive revisions in the classical theory of the firm. These revisions were stimulated by the manifest disparity between classical theory and observed practice. One of the more notable of these differences is exemplified by the way the pricing mechanism is employed. In the classical theory firms are supposed to maximize their profit. And the pricing mechanism is declared to be the most efficient method of allocating

resources in the market place. But if, as in Baumol's theory, firms only maximize sales revenue subject to a satisfactory-profit constraint; or if, as in the Behavioral Theory of the Firm, firms no longer maximize any criterion function; then the classical assertions about the efficacy of the pricing mechanism may also require revision.

As a further example, consider the assumptions contained in classical theories that have been called into question by these researches into decision-making behavior. In particular, consider the assumption that firms, or individuals, make decisions by maximizing a clearly defined decision function. All the evidence collected so far by these investigators supports the hypothesis that individuals and organizations make decisions by paying attention to a limited number of objectives, and by doing what they can to see that they meet these goals most of the time.^{22/} The objectives, however, are not stated in terms of clearly defined decision functions. On the contrary, they are usually stated in terms of past behavior, and current performance either is or is not up to these fairly flexible standards or objectives. If this is a reasonably accurate

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For an extensive and stimulating discussion of organizational decision-making behavior see: J. G. March and H. A. Simon, Organizations, John Wiley and Sons, 1958.

statement of the case, then the setting of prices, for example, can only be one of a number of organizational objectives. As a result a firm will only consider the altering of prices as one of the possible alternatives facing it at any point in time.

A corollary of this conclusion is that changes in the prices of a firm's inputs will also not have the effects on their decision processes that are asserted by classical theory. Firms do not equate marginal cost with marginal revenue. And even if they had some idea how to make these calculations, the pressure of satisfying competing goals would probably prevent them from carrying out and making use of such calculations.

It is apparent, therefore, that as behavioral theories are developed and tested that the conflict between the classical and the new will probably sharpen. And as I am reasonably convinced that the evidence will support the behavioral theories, I would expect to see some rather large and basic revisions being made in many branches of economic theory. These changes will not be induced because the revised theories are simpler or more elegant than classical ones. On the contrary, theories of individual and organizational decision-making behavior are almost certain to be more complex and less aesthetically pleasing than their classical counterparts. But what will cause the changes to occur is the simple fact that as more is learned about decision processes, theories will be constructed which will explain and predict a large part of many decision procedures.

As evidence for this claim and as an example of the manner in which these revisions may take place, consider the following example of a

behavioral theory of the trust investment process.^{23/}

The object of this research was to construct a theory that describes and predicts the portfolio selections of a particular trust investor. The theory was built by observing and incorporating the decision processes of the trust investor into a program for computer simulation. The theory was tested for its ability to predict the actual behavior of the trust officer by requiring it to select a series of portfolios for an actual set of trust accounts. These accounts were processed both by the trust officer and the theory during the first and third quarters of 1960. The portfolios chosen by the theory compared very favorably with those chosen by the trust investor. As a further test the decision processes by which the theory generated its portfolios were compared with the trust officer's recorded decision behavior. Even though it is not possible to say that the theory completely reproduces the recorded behavior, the evidence from these tests strongly supports the hypothesis that the theory explains a considerable portion of the trust investment process.^{24/}

Now a theory that describes and predicts one trust investor's portfolio selection process is still a long way from becoming a general theory of trust investment. But the evidence is there that theories can be built

^{23/}

G.P.E. Clarkson, Portfolio Selection: A Simulation of Trust Investment, Prentice-Hall, 1962.

^{24/}

For an extensive analysis of the results obtained from these tests see: ibid, Ch. 6 and 7.

that explain and predict, to a considerable level of detail, the decision processes of human decision-makers. Hence, if the success in building theories of individual behavior can be translated into theories of organizational and market behavior, then many branches of economic theory will undergo substantial alterations.^{25/}

So far I have been discussing the changes that may take place in the theories of various economic units, e.g., the firm. But if my prognoses are correct, then revisions that are made in the theory of the firm, for example, must also be reflected in the aggregate theories of market behavior. That is to say, if the firm is no longer to be pictured as a static, profit maximizing entity, then the theory that accounts for their aggregate behavior must also undergo some change. Clearly, if a firm is more accurately represented as a complex organization confronted with the task of satisfying many competing goals, the theory that accounts for their aggregate market behavior will have to take account of this fact.

As yet there is not a sufficient amount of data to suggest in any detail how such a revised market theory should be constructed. However,

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For a detailed examination of the way in which the economic theory of consumer behavior might be revised to accommodate a behavioral theory of consumer behavior see: G.P.E. Clarkson, The Theory of Consumer Demand: A Critical Appraisal, Prentice-Hall, Englewood Cliffs, forthcoming 1963.

one component it would have to include is the apparent lack of interest on the part of large corporations to engage in price competition. For example, Baumol has already observed that oligopolists will consider non-price competition to be the more advantageous alternative. Also the behavioral theory of the firm suggests that large firms, whether oligopolists or not, prefer to have a stable environment to work with. And one way to keep the environment stable is to avoid price competition. Hence, whatever form the revised theory finally takes it no longer is likely to represent the market as a place where firms struggle fiercely to meet price competition. Instead the theory should provide us with a more accurate picture of the nature of competitive markets and of the forces that influence the behavior of individual firms.

(b) Economic Policy

If we accept, for a moment, the supposition that the evidence will largely support the behavioral theories, then what will be the effect of these theoretical revisions on policy considerations? In particular, can we say anything about the amendments that may have to be made to our conception of how pricing policies should be regulated?

Classical theory, as mentioned earlier, asserts that competitive pricing is the most efficient way to keep the prices of finished products, e.g., consumer prices, as low as possible. Consequently, when competitive pricing appears to have vanished and one or two companies dominate an industry, anti-trust measures are invoked with the intent of restoring competitive pricing to that particular market. But if, as investigations

of business behavior suggest,^{26/} the pricing decision is only one of a firm's decision problems, then increasing the number of firms in the market may not have the desired effect. In other words, unless it can be shown that the number of firms in the industry has a direct effect on the prices that are set, it does not make much sense to invoke anti-trust measures whose purpose is to increase the number of competing firms.

For example, it has been observed in a number of cases that increases in internal administrative costs frequently lead firms to centralize their allocative processes.^{27/} In effect, these firms replace internal pricing mechanisms with central planning. Departments no longer maintain their own profit and loss figures, but instead work from allocated budgets and set prices. A further stimulant to centralized decision-making has been provided by the high speed computer. And it is perfectly clear that many firms are making full use of their data processing abilities. Now if most prices and budgets of large corporations are set by a central plan, then this plan will not be sensitive to external changes. Clearly, the vast amount of coordination required by central planning precludes the possibility of being very sensitive to external disturbances. Hence,

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For further discussion of this point see: H. A. Simon, "New Developments in the Theory of the Firm," Papers and Proceedings of the AEA, American Economic Review, Vol. LII, May, 1962, pp. 1-15.

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For example see: J. G. March and H. A. Simon, Organizations, John Wiley and Sons, 1958, especially, Ch. 7; and H. A. Simon, The New Science of Management Decision, op. cit. Ch. 5.

if prices within an industry are judged to be too high and anti-trust measures are invoked, then for these measures to be effective they must somehow directly affect some of the principle components of a firm's internal plan. Unfortunately, not enough is yet known about the planning process to suggest effective procedures for inducting the desired change. But the evidence is sufficient to call into question many of the traditional beliefs about the efficacy of market mechanisms in controlling prices.

As a further example of how policy conclusions may have to be revised, consider the traditional conception of a firm's reaction to various tax policies. In particular, let us examine the effect of levying a lump sum or poll tax on all corporations.

Under classical theory the assessing of a lump sum tax is supposed to be one of the most effective ways of taxing a corporation without having the cost of this tax passed on to the consumer. This conclusion is supported by the classical assertion, referred to earlier, that changes in fixed costs should be ignored when setting prices and output. But observations of business behavior do not support this assertion. On the contrary, firms have been observed to raise prices to compensate for increases in overhead costs. And under Baumol's analysis any increase in overhead costs, such as a poll tax, will be shifted, at least in part, to the consumer because, "when they are levied on him, the oligopolist will raise his prices and reduce his selling costs to a point where his

profit constraint is once again satisfied...Since no one seems to deny that businessmen do, in fact, often raise prices when their overheads increase this point must be accepted by someone who questions the sales maximization hypothesis."^{28/}

If the classical conclusion concerning the poll tax is in error, it is reasonable to suppose that other conclusions about tax policies are also erroneous. And if our conclusions about the efficacy of the price mechanism are also substantially correct, then it would appear that many of the standard notions about appropriate policies are also in need of re-examination. Clearly it would be pleasant to be able to point to all the errors and indicate the necessary corrections. But until a great deal more is learned about organizational behavior such a procedure is simply not feasible. The best that can be done is to point toward a few of the most likely candidates and hope by this approach to generate an attitude of healthy suspicion toward the remaining, unexplored conclusions.

(c) Business Decision-Making

If it is possible to point out the likely revisions in economic theory and its policy conclusions, then it is pertinent to inquire into the effects these changes may have on the business decision-maker. If and when our understanding of decision processes reaches the point where the "best" procedures can be prescribed, then the advances in economic theory

^{28/} W. J. Baumol, Business Behavior, Value and Growth, op. cit., p. 78.

will be of great importance to the businessman. But until the requisite knowledge has been acquired, it is perhaps more fruitful to examine the implications of current research for operations research. In other words, it seems more reasonable to examine the effects of recent research on the techniques of decision-making rather than on the process itself.

When operations researchers first tried to employ traditional economic models to business problems, they discovered that important changes had to be made if these models were to be successfully applied. Out of this search for new analytical techniques innovations like linear programming, game theory, and statistical decision theory evolved. These techniques have been successfully applied to a large number of business problems. And it is perfectly clear that the application of operations research techniques has become an established tool in management's decision process.

The advent of heuristic programming, however, opens up an important new class of problems. It will allow operations researchers to begin to tackle problems that previously were far too complex and ill-structured to be solved by standard techniques. For example, one of the earliest uses of this technique is in the analysis and synthesis of electric motor design. Ten years ago, in one company, engineers worked out the designs for standard and special order electric motors. Today, a computer, programmed with a relatively simple heuristic program, takes customers' orders for many types of electric motors, generators, and transformers

and sends the design specifications to the factory floor.^{29/} Earlier we described Tonge's line balancing program which by combining heuristics and some simple mathematical techniques was able to schedule assembly operations as well as, if not more efficiently than, skilled industrial engineers. Indeed the technique of heuristic programming has made it possible to develop programs which will solve many of the problems that have traditionally been the concern of middle management.

The fact that it is now technically possible to begin replacing managers with heuristic programs does not imply that it is yet economically desirable to do so.^{30/} For example, consider the case of the trust officer at a bank. The evidence gathered so far suggests that his job of selecting portfolios for trust accounts could be taken over by a suitably programmed computer. The evidence also suggests that the computer can be programmed to select its portfolios for the same reasons as the human investor. Presumably, the computer could even be taught how to improve upon its performance. But, before a computer will ever replace a trust investor, it has to be shown that it is either more

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G. L. Goodwin, "Digital Computers Tap Out Designs for Large Motors Fast," Power, April, 1958.

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For an extremely interesting analysis of the future role of computers in management decision-making see: H. A. Simon, "The Corporation: Will it be Managed by Machines?" in, M. Anshen and G. L. Bach (eds), Management and Corporations 1985, McGraw-Hill, New York, 1960.

efficient or cheaper to employ a computer instead of the trust investor. As yet the evidence on this point is far from clear. And the flexibility of the human problem solver is still orders of magnitude greater than that of current computer programs. But, as our programming abilities develop and our understanding of problem solving behavior grows, I am convinced that heuristic programming will become one of the primary tools in management's decision-making apparatus.

Conclusions

In the last few pages I have made a number of fairly strong statements about the current state of economic theory. I have also pointed out some of the effects that the proposed revisions of economic theory may have on government policy and business practice. And on more than one occasion I have noted that the current state of our knowledge is insufficient to identify and assess these changes with any significant degree of accuracy. However, the reason for this state of affairs is easy to identify. Economists have an abundance of theories but a dearth of facts. And until this situation is corrected the best we can do is point to the difficulties and hope for the best.

Consequently, if we are to understand decision processes, and if we are to use this knowledge to assist in public and private decision procedures, then a large amount of effort must be devoted to empirical

research. This research will have to focus on the decision-making processes of individuals and organizations. And unlike a good deal of previous research, it will have to be conducted in a reasonably systematic way.

For example, most of the information we have about business behavior is derived from economists' and operations researchers' anecdotes, and sample surveys of business behavior. Neither are very reliable sources of information. The former are subject to bias by the observer's preconceptions. And the latter contain, as a rule, scanty pieces of ill-supported and unverified data. As a result, whether we are satisfied or not with classical theories, there is no solid foundation of data from which to develop and test.

However, the scarcity of reliable data is not a result of a paucity of ways for collecting it. On the contrary, intensive interviews, detailed observations, and the techniques employed in simulation studies are all useful methods for gathering and sorting data. And since the number of untested hypotheses far exceeds the available data it is toward this objective that the emphasis on empirical research should be placed.

